Flight Opportunities

Additively Manufactured Ceramic Rocket Engine Components

Completed Technology Project (2017 - 2020)

Project Introduction

HRL Laboratories, LLC, with Vector Space Systems (VSS) as subcontractor, proposes a 24-month effort to develop additive manufacturing technology for reinforced ceramic rocket engine components. The technology will be specifically applied to VSS' LOX/propylene rocket engines in the 800-lbf thrust class and will result in greater than 10 times cost reduction, greater than 10 times reduction in fabrication time and could increase payload by over 10 percent by allowing the integration of complex features that would not be manufacturable otherwise. By maturing this unique process to 3D-print high-temperature ceramics beyond the tipping point for commercialization, a range of aerospace and other applications could benefit from rapid, low-cost fabrication, including upper stage rocket engine chambers/thrusters for small launch vehicles, in-space thrusters for spacecraft, as well as high-temperature components in turbo-pump and combustion devices for larger launch vehicles. We have invented inexpensive pre-ceramic resins that can be printed with conventional stereolithography (SLA) 3D printers [Science Vol 351, p.58 2016]. After printing, the polymer parts can be converted to ceramic by firing in inert atmosphere at 1000-degrees C, offering a 10 times faster and 10 times less expensive method to produce ceramic rocket engine components compared to conventional processing out of ceramic matrix composites. By incorporating fiber reinforcement, the ceramic engine can be toughened and strengthened, averting the brittle fracturing commonly associated with ceramics. Compared to refractory metal-based components, the cost savings are even larger. Our breakthrough in additive manufacturing of polymer-derived ceramics combines the ease, flexibility and low-cost of polymer stereolithography with the high-temperature capabilities of SiC-based ceramics. By avoiding conventional powder-based ceramic processing routes, we will achieve fully dense ceramics with exceptionally high strength. Our most mature 3D-printed silicon oxycarbide (SiOC) ceramic composition exhibits high strength of 300 MPa and survives temperatures of 1700-degrees C for multiple hours. Printed parts can be easily joined in the polymer stage to fabricate ceramic structures that are larger than the build volume of the 3D printer. Together with VSS, HRL will mature the technology from TRL 4 to TRL 6, and scale up fabrication, culminating in hot fire testing of high-performance 800-lbf thrust class LOX/propylene rocket engines with novel designs enabled by additive manufacturing. After successful completion of the proposed program, HRL plans to commercialize the 3D printing technology and make it widely available.

Anticipated Benefits

The technology will be specifically applied to VSS' (liquid oxygen) LO1/propylene rocket engines in the 800-lbf thrust class and will result in greater than 10 times cost reduction, greater than 10 times reduction in fabrication time and could increase payload by over 10 percent by allowing the integration of complex features that would not be manufacturable otherwise.

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Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Lead Organization:

HRL Laboratories, LLC

Responsible Program:

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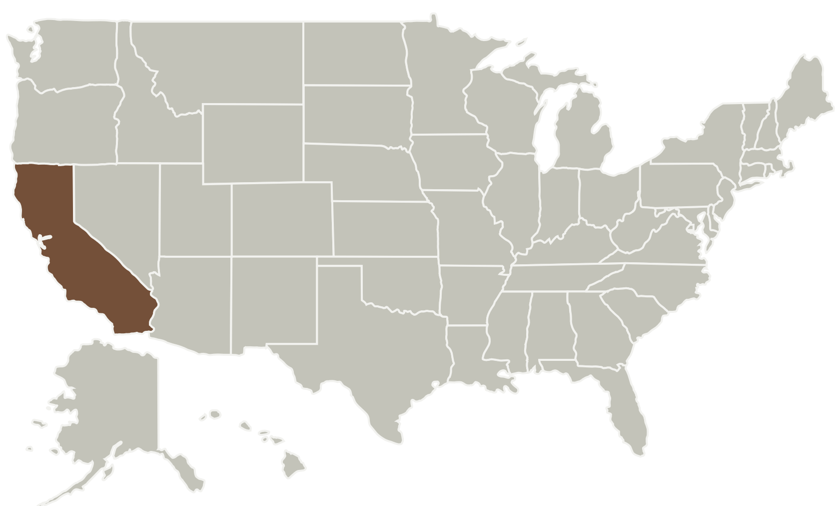
Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
HRL Laboratories, LLC	Lead Organization	Industry	Malibu, California

Primary U.S. Work Locations
California

Project Management

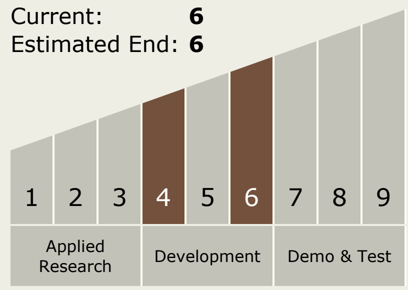
Program Director:
Christopher E Baker

Program Manager:
John W Kelly

Principal Investigator:
Tobias A Schaedler

Technology Maturity (TRL)

Start: **4**
Current: **6**
Estimated End: **6**



Target Destination

Earth

Project Transitions

June 2017: Project Start

September 2020: Closed out

Closeout Summary: Development of and hot firing additively manufactured high-temperature materials applicable to rock et engine components. The goal is technology that can be applied to small and large engines for launch vehicles. Although completion was delayed because of COVID issues affecting the test facility, the final testing was completed in September of 2020.

Project Website:

https://www.nasa.gov/directorates/spacetech/home/index.html